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Wind-Diesel Systems in Alaska: A Preliminary Analysis

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Most remote rural communities in Alaska use diesel to generate electricity, but the high price of diesel is causing an increasing number to add a local power source that's also renewable—wind.

Wind-diesel systems combine power from diesel generators and wind turbines. They're intended to cut the cost of electricity in remote places, while at the same time increasing the use of renewable energy. And although building wind systems is expensive, once they're in place the cost of wind is stable—unlike diesel prices, which are volatile.

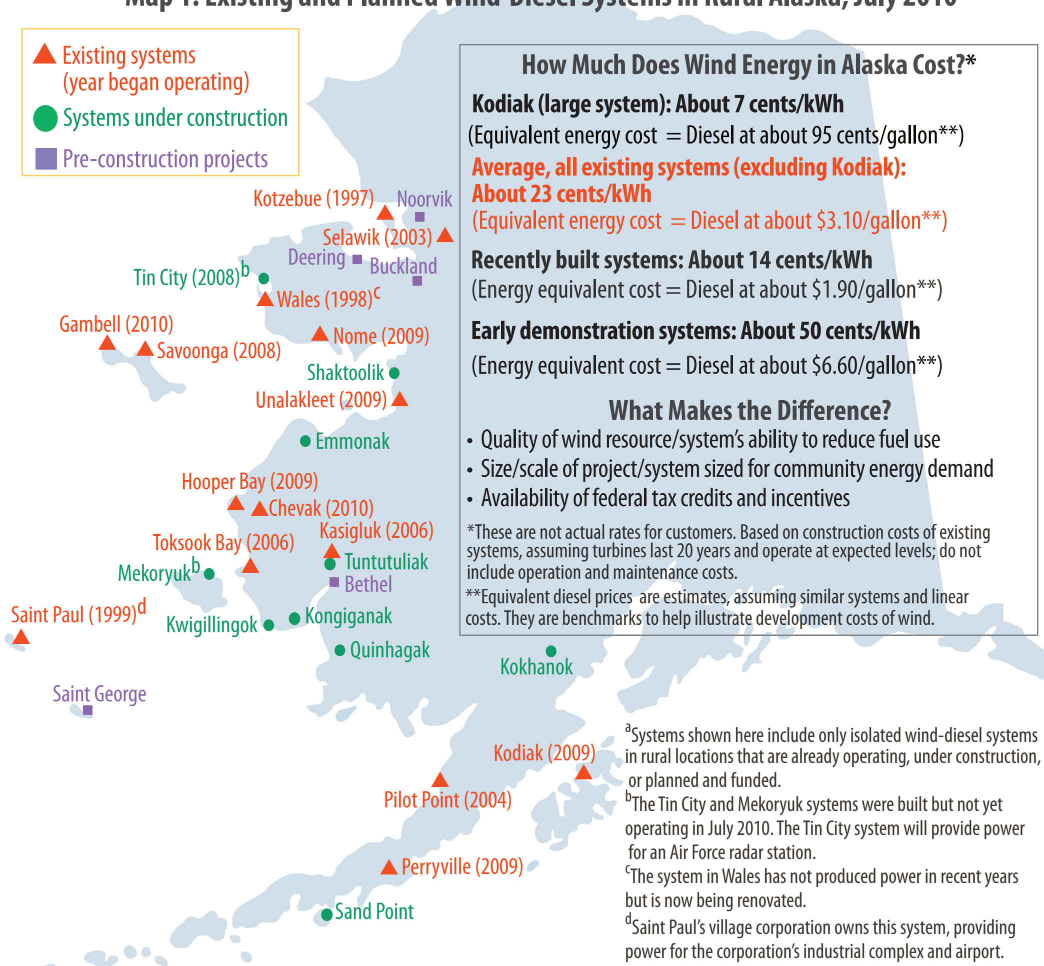
But so far there's been no broad analysis of wind-diesel systems in Alaska. Do they generate as much electricity as expected? Do they produce power at lower cost than conventional diesel systems? The Alaska Energy Authority asked ISER and the Alaska Center for Energy and Power to assess the performance of existing rural systems.

The Alaska Energy Authority administers the Alaska Renewable Energy Fund, which is now investing $20 million to $30 million a year building rural wind-diesel systems. The Denali Commission and private industry have also funded some projects. Map 1 shows rural systems operating, under construction, and funded but not yet built.

Our analysis is preliminary; most existing systems are new. Adding wind to diesel systems makes economic sense to customers if wind energy costs less than the equivalent energy cost of diesel. We found:

- *The cost of wind energy from existing systems ranges from about 7 cents to 50 cents per kilowatt-hour.* That estimate is limited to construction costs and assumes the systems operate 20 years. Energy from newer, larger, or more efficient systems is typically least expensive.
- *On an energy-equivalent basis, the average cost (construction only) of wind energy from recently built systems is comparable to diesel at around $1.90 a gallon.* Diesel prices reported by many rural utilities in 2009 were in the range of $4 to $5 a gallon, with a few above $7.
- *Installing wind power likely adds around 4 cents to 8 cents* per kilowatt-hour to utilities' operating and maintenance costs. (This rough estimate is based on limited data and experience operating these systems.)
- *Existing systems generate an annual average of from 5% to 55%* of local electricity. Most projects have yet to exceed 25%, but that's expected to increase, when recently built systems gain more operating experience—and when new systems come online, with the benefit of past experience and improved equipment.
- *Most systems installed since 2006 are meeting or exceeding model estimates* of electricity production. They benefit from strong wind resources, reliable turbine manufacturers, and experienced developers and operators.
- *The current Power Cost Equalization (PCE) formula doesn't reward utilities that develop wind power* (or any other renewable resource). PCE is a state program that subsidizes part of the high cost of electricity in small rural places. But under the existing system, utilities collect more if they use more fuel—and less if they reduce fuel use by adding wind power or otherwise conserving fuel (see page 4).

Map 1. Existing and Planned Wind-Diesel Systems in Rural Alaska, July 2010[a]



[a]Systems shown here include only isolated wind-diesel systems in rural locations that are already operating, under construction, or planned and funded.

[b]The Tin City and Mekoryuk systems were built but not yet operating in July 2010. The Tin City system will provide power for an Air Force radar station.

[c]The system in Wales has not produced power in recent years but is now being renovated.

[d]Saint Paul's village corporation owns this system, providing power for the corporation's industrial complex and airport.

Sources: Alaska Energy Authority, Wind Energy Program; authors' estimates

Snapshot of Wind-Diesel Systems

Our analysis found that most rural wind-diesel projects so far seem economically justifiable, assuming a steady output of wind power for 20 years. But no system has been operating in Alaska for nearly that long. The earliest projects date from the late 1990s, and more than 75% of the installed capacity has been in place less than two years.

Integrating wind into isolated diesel power plants is challenging, because wind fluctuates—and as wind provides more of the electric demand, integration becomes increasingly complex. The wind-diesel systems built so far in rural Alaska vary considerably in their construction costs, the size of the turbines, and the installed capacity (Figure 1). Some can also supply much more of the electric load than others. The percentage of electricity wind power supplies in a wind-diesel system is known as "wind penetration."

Wind-diesel systems can be classified into low, medium, and high penetration. All three types of systems have been built in rural Alaska. The amount of wind power on the grid determines what ancillary equipment is needed for power control and energy storage. Figure 2 shows examples of system configurations—but there are also many other variations.

- Low-penetration systems cost less to build and don't overly complicate the existing power plant. But wind energy generates only up to 20% of electric demand and doesn't reduce fuel use as much.
- Medium-penetration systems are costlier to build and more complex to operate, but wind energy generates up to half of electric demand, displaces up to half the diesel, and potentially provides energy for space heating or other uses, like electric cars.
- High-penetration systems are the costliest and the most complex to operate, but wind generation has the potential to supply a large share of electric demand and also provide considerable energy for heating or other uses.

Figure 1. Types and Construction Costs of Existing Wind-Diesel Systems (July 2010)

Size of Turbines/Installed Capacity
2.4 kW/24kW (Perryville) - 1,500 kW/4,500kW (Kodiak)

Construction Costs
(Per installed kilowatt)
$4,000 - $15,000

Types of Systems
(Based on annual average wind penetration)

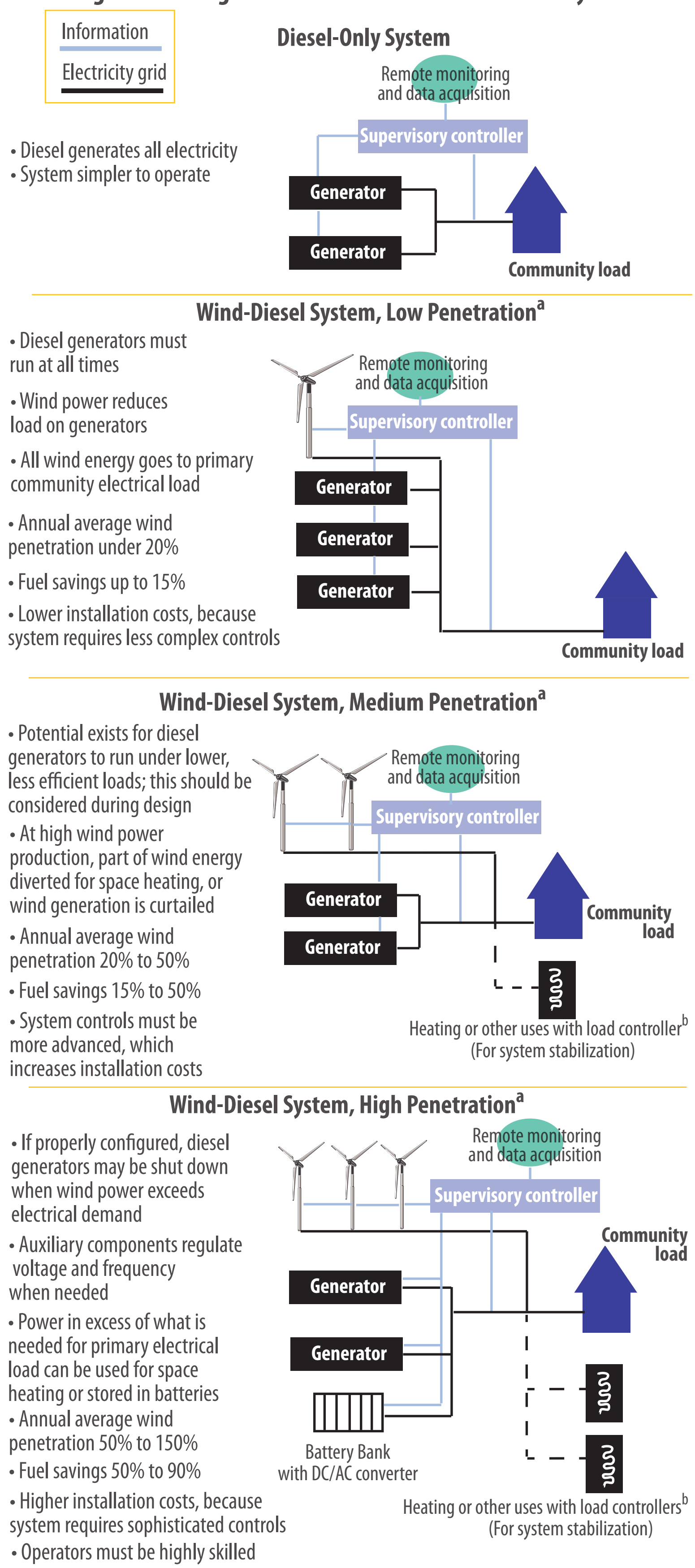
Low	*Medium*	*High*
Kotzebue	Toksook Bay • Hooper Bay	Saint Paul
Nome	Kasigluk • Savoonga	Wales*
Selawik	Unalakleet	
Perryville		

*Wales' wind system has not generated power in recent years, but it was designed as a high-penetration system and is being renovated.

Notes: Figure does not include systems currently under construction.
About 80% of Kodiak's electricity is from hydroelectic. The new wind system displaces about half the diesel previously used to supplement local electricity, but it does not meet the standard definition of a "high-penetration" system because most of Kodiak's electricity is generated by hydropower, with diesel and now wind supplementing as needed.

Sources: Denali Commission; utilities; wind-developers; Alaska Energy Authority

Figure 2. Configuration of Diesel and Wind-Diesel Systems



[a]Wind penetration is the percentage of electricity supplied by wind.
[b]Besides residential or commercial heating, possible other uses include charging electric cars.
Note: These are examples of systems; other configurations exist.
Sources: Authors' compilations

Performance of Existing Systems

Many areas of Alaska—especially along the coast—have plenty of the most important resource for wind-diesel systems: wind (Map 2). But adding wind systems to isolated diesel power plants in rural Alaska has at times been controversial. More than a decade ago, when the earliest demonstration projects were built, some people thought wind turbines and other hardware couldn't stand up to arctic conditions.

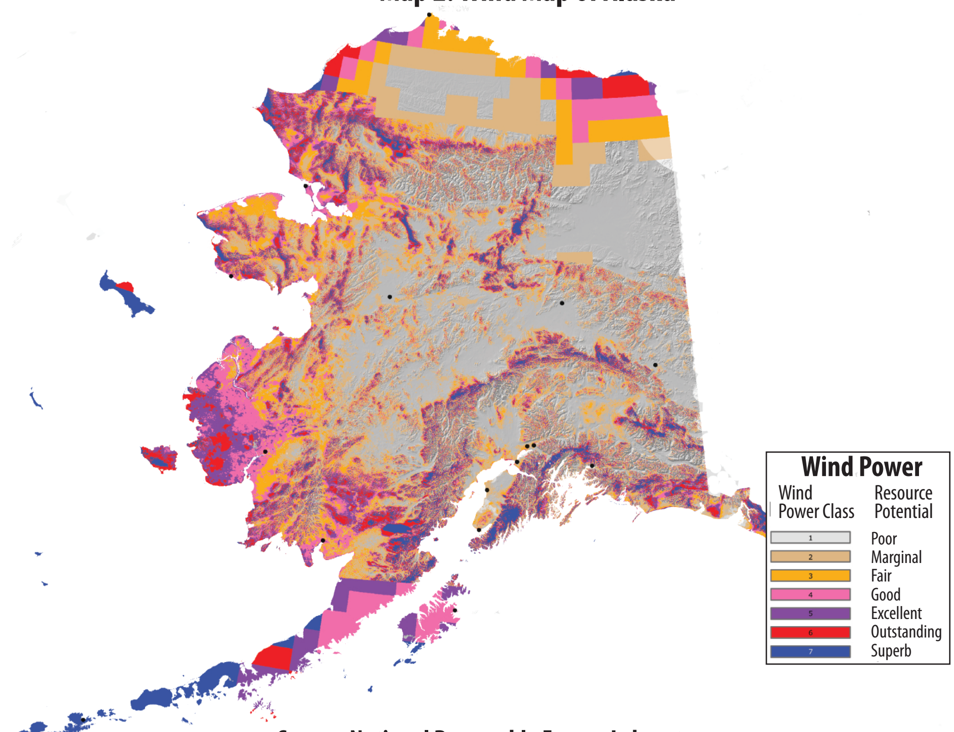
In fact, early projects (such as in Kotzebue) did face a number of hardware problems and setbacks. Subsequent systems have also required adaptations for arctic conditions—for example, installing turbine foundations in discontinuous permafrost has proved much more difficult and expensive than in more temperate climates.

The required adaptations for wind systems in Alaska make them particularly expensive in the smallest, most remote locations. But diesel prices are also highest in these small isolated communities.

The newest systems are doing considerably better than earlier projects (Figure 3). Several are producing electricity from wind at or near computer model estimates. The performance of others is expected to improve, as they ramp up to full operation or are renovated.

Figure 4 shows how much electricity existing systems are producing from wind—compared with wind-model estimates of what they could produce—and what factors are affecting their performance. While conditions are different for each system, several factors are common among the top-performing systems:

Map 2. Wind Map of Alaska

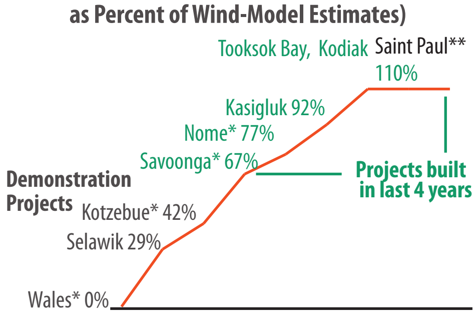


Source: National Renewable Energy Laboratory

- Wind resource of class 6 (outstanding) or 7 (superb)
- Reliable turbines
- Experienced wind-developers and utilities
- Skilled local system operators

Figure 3. Improved Performance of Newer Wind-Diesel Systems

(Actual Kilowatt-Hours Produced by Wind, as Percent of Wind-Model Estimates)



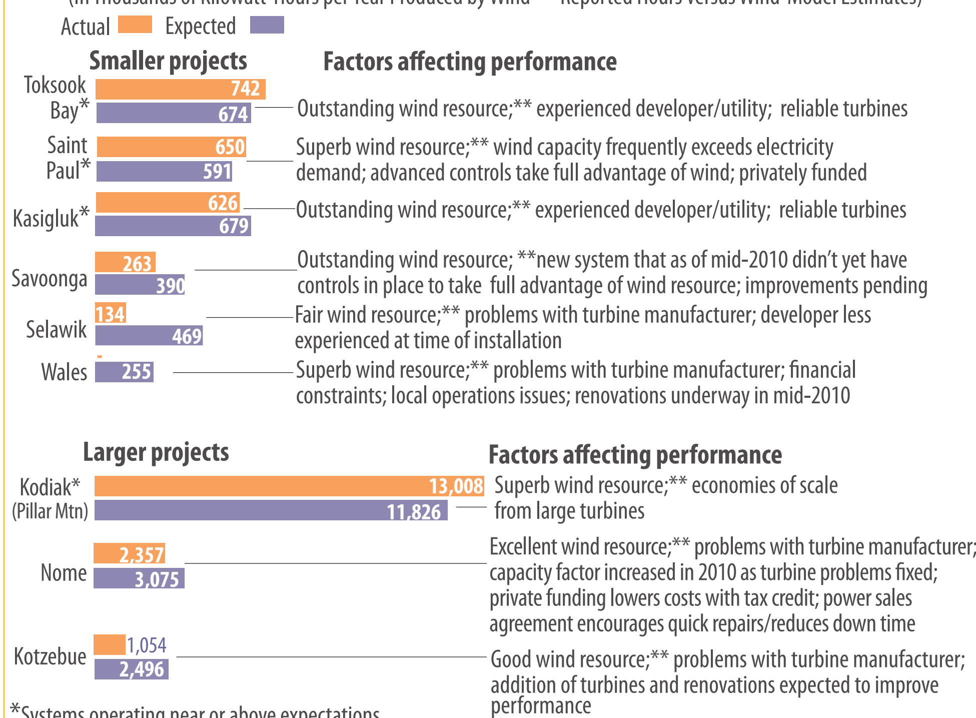
*System being renovated or still ramping up to full operation; see Figure 4.

**Built in 1999, this system is the exception: an early but high-performing system; the developer had significant experience in wind-diesel systems.

Source: Utility information, Power Cost Equalization Program data

Figure 4. Actual versus Expected Performance, Existing Wind-Diesel Systems

(In Thousands of Kilowatt-Hours per Year Produced by Wind— Reported Hours versus Wind-Model Estimates)



*Systems operating near or above expectations

**Wind resources are divided into seven classes, from those with the least to the best potential for generating power: Class 1: poor; Class 2: marginal; Class 3: fair; Class four: good; Class 5: excellent; Class six: outstanding; Class 7: superb

Note: Adequate data aren't available for all existing systems.

Sources: Utility information, Power Cost Equalization Program data; HOMER model estimates

PCE and Wind Power

The state government established the Power Cost Equalization (PCE) program in the 1980s to help bring the cost of electricity for rural Alaskans closer to what urban residents pay, and to help small rural utilities, which struggle with high costs.

PCE pays eligible utilities part of the cost of the first 500 kilowatt hours per residential customer per month. But some utility operators and analysts told us they think this formula penalizes rural utilities that add wind (or any other renewable) power.

In response, we constructed a comparative cost model to assess the effects of the current PCE formula on wind-diesel and diesel-only systems. Figure 5 describes the issue and illustrates it with an example.

Essentially, rural utilities that add wind power may not get the full economic benefit —because when they reduce the price of electricity by reducing their fuel use, they lose part of their PCE subsidy and also increase their operating costs.

We estimate that to make up for the smaller PCE subsidy and higher operating costs, utilities would have to cut their fuel costs very substantially—by generating about 40% of electricity with wind. But most existing systems generate less than 25%.

Figure 5. Why Might the Power Cost Equalization Formula Discourage Rural Utilities from Adding Wind Power?

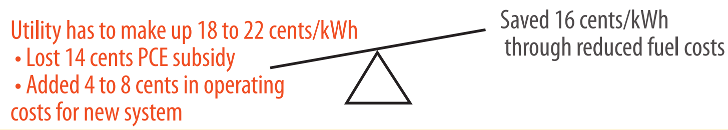
Current PCE formula pays part of the cost for first 500 kWh per residential customer per month*

- Assumes that eligible utilities use only diesel to generate electricity
- Pays utilities more as they use more fuel or as fuel prices increase
- Gives customers little incentive to conserve until use reaches at least 500 kWh per month

Example: Kasigluk Utility

	Old System (Diesel-Only)	New Wind-Diesel System (Wind generates 22% of electricity)	Changes
Price of electricity (per kWh)	70 cents	54 cents	Down 16 cents: wind power reduces fuel use
PCE subsidy (per kWh for first 500 kWh per residential customer)	53 cents	39 cents	Down 14 cents: fuel use and electricity price drop
Non-Fuel costs	Operating/maintaining diesel-only system	Operating/maintaining more complex system	Up 4 to 8 cents/kWh

Model Estimates for Kasigluk Utility, with Wind Generating 22% of Electricity



How Might PCE Provide More Incentive but Still Help Offset High Electricity Costs?

Consider changing PCE system to cover entire cost of a much lower baseline amount of electricity—for example, 200 to 300 kWh per month.

- Would give utilities more incentive to reduce fuel use and allow them to fully capture economic benefits from adding wind power, even at lower wind-penetration levels
- Would give customers more economic incentive to conserve energy and support use of wind power

*Communities eligible for PCE subsidies are determined by state statute, based on costs of electricity; currently 184 small communities are eligible. The PCE program also subsidizes the first 70 kWh of use per person per month for community facilities in eligible communities.

Sources: Utility PCE and RCA filings and ISER model estimates

To give rural utilities more incentive to use renewable energy—a goal of the state Renewable Energy Fund—and to encourage conservation, we suggest the state consider a different PCE formula. Instead of paying part of the cost of the first 500 kilowatt hours a month per residential customer, the state might cover the entire cost of a smaller amount—perhaps in the range of 200 to 300 kilowatt hours.

More analysis is needed to determine the optimal PCE system. But policymakers should consider ways to structure PCE to work in concert with the state's renewable energy goals—and reward rural utilities that make the substantial effort to reduce costs for their customers.

Conclusions

A number of wind-diesel systems in remote locations are generating as much electricity as wind models predicted. This is an important observation, because it was not clear whether wind projects in Alaska achieve the level of generation wind models estimated they would.

But our review of project histories did reveal some potential ways of improving the economics and performance of rural wind-diesel systems. Those include geographically and technologically aggregating projects to take advantage of economies of scale; employing skilled project developers who use technological innovations to increase wind-energy generation; having clear power-purchase agreements; having skilled and motivated local operators; establishing remote monitoring to alert project managers about problems and record maintenance and performance data; and hiring people with expertise in Alaska's harsh climate. It's also important to look for ways to streamline project construction, including the permitting and land-leasing processes. And while federal tax credits available to private developers can substantially reduce energy costs for consumers, those credits haven't been used much in Alaska because state or federal grants have paid for most construction.

We also found that a detailed wind assessment is critical during project planning; not surprisingly, wind systems in places with poorer wind classes don't do as well.

Most Alaska wind projects so far seem to be economically justifiable, assuming steady production of electricity for 20 years—but no system has operated for nearly that long. The limited data available about many existing systems made our work more difficult, as did the fact that there is currently no consistent reporting of either construction costs or system performance. Standard reporting requirements for publically funded projects would improve future analyses.

This summary is based on *Alaska Isolated Wind-Diesel Systems: Performance and Economic Analysis*, by Ginny Fay, Katherine Keith, and Tobias Schwörer, prepared for the Alaska Energy Authority and the Denali Commission, June 2010. The findings and conclusions are those of the authors. It is available on ISER's website: www.iser.uaa.alaska.edu.

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